Compatibility and Decontamination of High-Density Polyethylene Exposed to Sulfur Mustard

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Introduction

The Explosive Destruction System (EDS, Fig. 1) developed by the U.S. Army Chemical Materials Activity, is utilized by the U.S. Army Edgewood Chemical Biological Center to destroy chemical warfare material in an environmentally safe manner and with no adverse affects to its operators. The system uses cutting charges to explosively access chemical munitions prior to their chemical neutralization. One of the challenges in EDS operations is the transport and insertion of munitions that have developed leaks. These leaking munitions pose hazards to workers and the environment. Therefore, establishing a method to handle the leaking munitions safely is extremely important. To combat this hazard, the construction of a universal munition storage container (UMSC) was proposed. For this project, HDPE was chosen for the construction of the UMSC. Leaking and non-leaking mustard munitions were stored in the UMSC until destruction in the EDS. The UMSC containing the munitions was placed directly in the EDS and was destroyed along with the munition, thereby eliminating direct handling of the munitions, leaking or otherwise. This experiment evaluates the compatibility of HD and HDPE and the ability to decontaminate the material after a simulated bench-scale EDS operation.

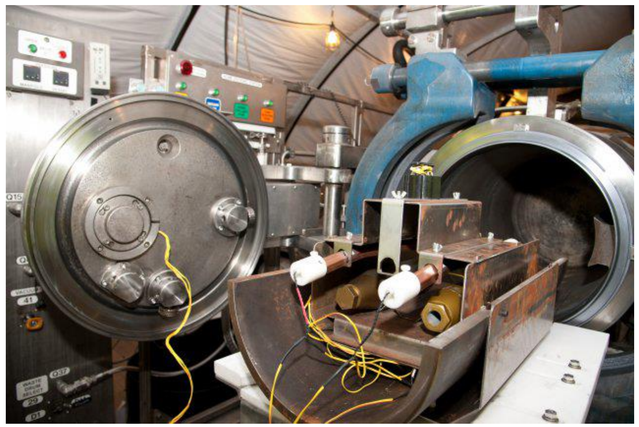

Figure 1. Two munitions being placed in the Explosive Detection System.

Materials and Methods

Task 1 – HDPE Compatibility with HD. The purpose of Task 1 was to visually observe the compatibility of HD with HDPE and to measure weight changes over time in the HDPE after it was soaked in HD. An additional goal was to determine whether the amount of HD adsorbed onto and absorbed into the coupon increased with time. For this task, 32 random HDPE coupons, cut from smooth and jagged exploded pieces of UMSCs and approximately 1–2 g in mass, were placed in 40 mL volatile organic analysis (VOA) vials and weighed. Each coupon was spiked with 2 mL of HD (Fig. 2). The samples were placed in storage at ambient temperature for time periods ranging from 1 to 12 weeks. Once weekly, 2 sample coupons were removed from storage for observation (Fig.3). Each sample was photographed, and any observational changes to the HD and HDPE were recorded. The coupon was then removed from the HD, towel-dried, and weighed. Each coupon was placed in a new VOA vial and rinsed with hexane. The hexane rinsate was diluted and analyzed for HD.

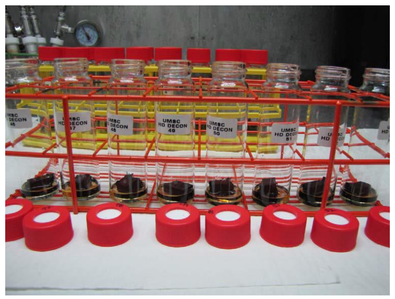

Figure 2. Task 1 coupons spiked with 2 mL of HD for storage.

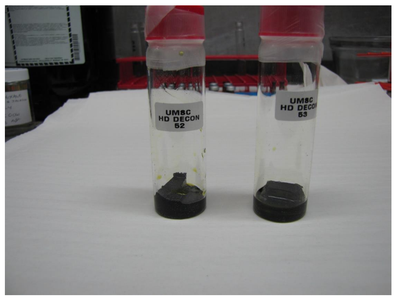

Figure 3. Task 1 coupons after 27 days of storage. The dark green color was caused by oxidation due to the presence of copper in the HDPE.

Approved for Public Release

Abstract

The Environmental Monitoring Laboratories, in cooperation with the Chemical Operations Branch of the U.S. Army Edgewood Chemical Biological Center (ECBC) Directorate of Program Integration (DPI), conducted a multi-week study to determine the compatibility of high-density polyethylene (HDPE) with liquid mustard (HD) material and decontamination of HDPE when exposed to HD. In Part I of the experiment, we tested the compatibility of HD with HDPE to determine the amount of HD adhered or adsorbed onto the material and to observe any physical degradation of the material when exposed to HD over time. In Part II of the experiment, we evaluated the ability of HDPE to be decontaminated after it had been in contact with HD for short and extended periods of time. Both parts of this experiment will be used to determine the feasibility of utilizing HDPE in the construction of universal munition storage containers for leaking and non-leaking HD munitions until their eventual neutralization in the Explosive Destruction System.

Materials and Methods (cont'd)

Task 2 – Decontamination of HPDE and HD by EDS Simulated Treatment. Task 2 evaluated the ability to decontaminate the HDPE that had come into contact with HD for short and extended time periods. Approximately 40 HDPE coupons, cut from smooth and jagged exploded pieces of UMSCs and approximately 1–2 g in mass, were placed in VOA vials and weighed. Twenty coupons were spiked with 2 mL of HD and put aside for 30 min on the same day that they were treated (Fig. 4). The remaining 20 coupons were spiked with 2 mL of HD and stored at ambient temperature for 35–56 days, with 5 coupons treated during each operational week of the study. Twenty milliliters of monoethanolamine (MEA) was added to each coupon at 60° C for 1 h (Fig. 5). The sample containers were placed in a sand bath and insulated with aluminum foil to retain heat (Fig. 6)The MEA was decanted, followed by the addition of 20 mL of water at 60–95° C for 1 h. The water was then decanted. This process closely mimicked the destruction process used in the EDS. The drained MEA and water rinse were extracted and analyzed separately to determine the residual concentration of HD in each matrix. A treatment goal of 50 ppm (50,000 µg/L) in MEA for the EDS neutralent was established. Following the water drain, the coupon was vapor-washed with nitrogen for 15 min, placed in a 10 × 10 in. plastic bag, sealed, and allowed to off-gas for 1 h. A 10 L vapor sample was collected using thermal desorption tubes and analyzed for HD. The coupon was placed inside a clean VOA vial and rinsed with hexane. The hexane rinsate was analyzed to determine whether any residual HD could be recovered. Finally, the coupon was dried with laboratory towels and the final coupon weight was recorded.

Figure 4. Task 2 coupons and a metal blank spiked with HD before treatment. The metal blank was used to verify that the HDPE was not interfering with the reaction between HD and MEA.

Figure 5. Addition of MEA.

Figure 6. Reaction and bath showing bowl resting on hot plate surface. A small stir bar was added to each VOA vial. Foil was wrapped around the bowl for temperature control, and a thermometer was inserted into the sand bath to monitor temperature.

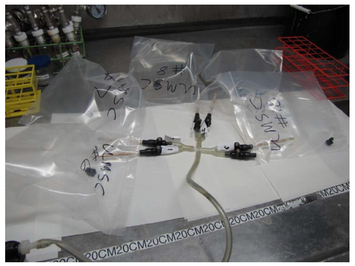

Figure 7. Depot area monitoring system (DAAMS) tube sampling of coupons. A 10 L air sample was collected to mimic the Tedlar bag air sampling of the EDS used to verify that it is safe to open the EDS door. Sample were collected at a flow rate of 500 mL/min for 20 min.

Results

The results of the compatibility tests can be found in Table 1. The data for coupon numbers 1–10 (HD treatment goals were not met) were used to fine-tune the decontamination procedure conditions. It was determined that a sand bath that fully encapsulated the 40 mL VOA vial and the addition of a stir bar (used to simulate the cavitation caused by a rotating EDS vessel) were necessary to more accurately simulate the EDS destruction operation. The results from those failed trials are not included in the data tables.

Table 1. HD and HDPE Compatibility Data

Coupon Number	Start Weight (g)	Holding Time (Days)	Weight After HD Removal (g)	HD in Hexane Rinse (µg/L)	Residual HD from Coupon (g)	End Weight of Coupon (g)
46	1.36	5	1.36	259,200	0.010	1.35
47	1.22	5	1.23	160,810	0.0064	1.23
48	1.41	13	1.42	179,560	0.0072	1.41
49	1.23	13	1.24	81,170	0.0032	1.24
50	1.12	20	1.13	169,250	0.0068	1.12
51*	1.48	20	1.49	123,290	0.0049	1.49
52*	1.59	27	1.62	378,340	0.015	1.60
53*	1.35	27	1.37	301,750	0.012	1.36
54	1.14	35	1.15	121,500	0.0049	1.15
55	1.33	35	1.36	263,890	0.011	1.35
56	1.28	41	1.30	78,020	0.031	1.30
57	1.74	41	1.71	102,060	0.0041	1.71
58*	1.74	48	1.81	381,380	0.015	1.81
59*	1.52	48	1.53	500,410	0.020	1.53
60*	1.66	56	1.79	254,430	0.010	1.78
61	1.24	56	1.27	130,110	0.0052	1.27
62*	2.10	60	2.11	104,440	0.0042	2.11
63*	1.47	60	1.50	442,530	0.018	1.49
64*	1.62	69	1.64	199,810	0.0080	1.64
65*	2.02	69	2.05	276,170	0.011	2.05
66*	1.01	76	1.03	235,050	0.0094	1.02
67*	1.06	76	1.08	105,510	0.0042	1.07
68*	1.11	83	1.13	362,960	0.015	1.13
69*	1.15	83	1.18	337,180	0.014	1.18

*Samples showed partial or full oxidation as indicated by a color change from orange to green.

Discussion

Task 1 – HD and HDPE Compatibility. HD either adhered to and/or was absorbed by the HDPE coupons. To some degree, HD was recovered by washing with hexane. HD did not cause any observable visual degradation in the HDPE. The amount of HD absorbed/adsorbed onto the coupons did not increase significantly over time (Fig. 8). Most likely, the data fluctuations can be attributed to the drying step of the procedure. The HDPE coupons did not show significant weight increase after the HD drying step or after the hexane rinse step.

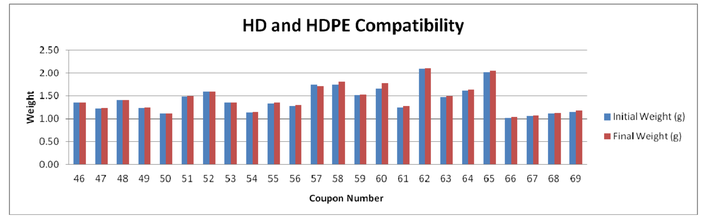

Figure 8. Comparison of initial and final coupon weights.

Task 2 – Decontamination. Data analyses for same-day decontamination demonstrated that the HDPE did not interfere with the neutralization of agent in the EDS bulk reaction liquid, and the HD concentration of <50 ppm (50,000 µg/L) treatment goal was achieved for the neutralent (data not shown). There was little to no change in the pre- and post HD coupon weights. Comparison with the metal blanks showed that residual HD adhered to the HDPE coupons throughout the decontamination procedure and could still be detected at low levels after MEA decontamination and water rinsing. In almost all cases, HD was detected on the DAAMS tubes sampling the Tedlar bag vapor. This suggests that clearing the inside of the vessel to open the door may be an issue in EDS operations. Data analyses of pre-treated coupons revealed that the HDPE did not interfere with the established EDS reaction conditions and the HD concentration of <50 ppm (50,000 µg/L) treatment was achieved. There was little to no change in the beginning and ending coupon weights. In all cases, HD was detected on the DAAMS tubes sampling the Tedlar bag. The amounts of HD detected in the MEA and hexane rinses were significantly higher in the pretreated coupons than in the same-day treated coupons, showing that the HD adhered more to the HDPE over time. However, the increased HD-HDPE contact time did not increase the amount of absorbed HD (data not shown).

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